Water and Carbon Capture and Storage

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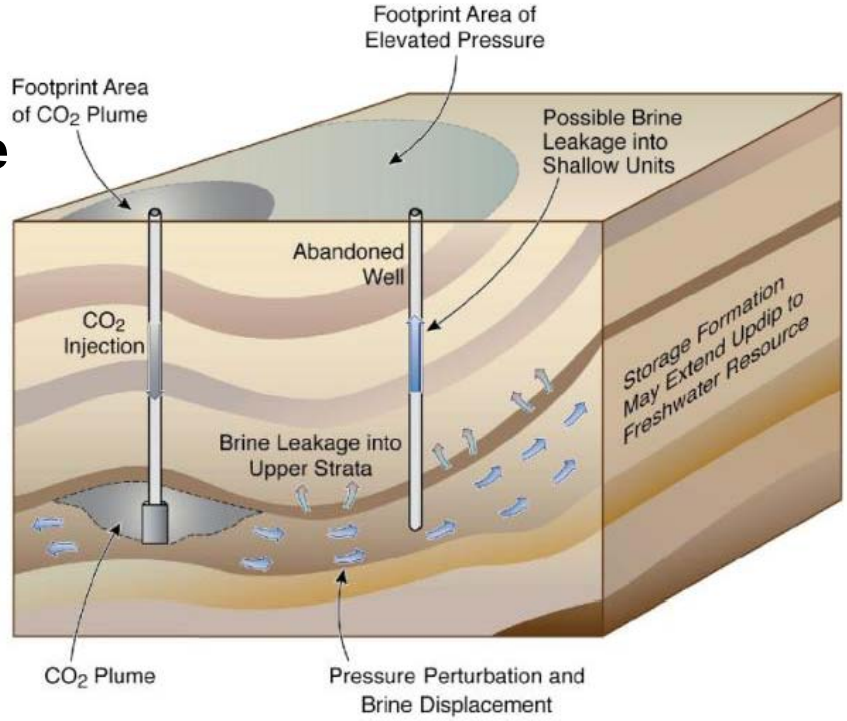
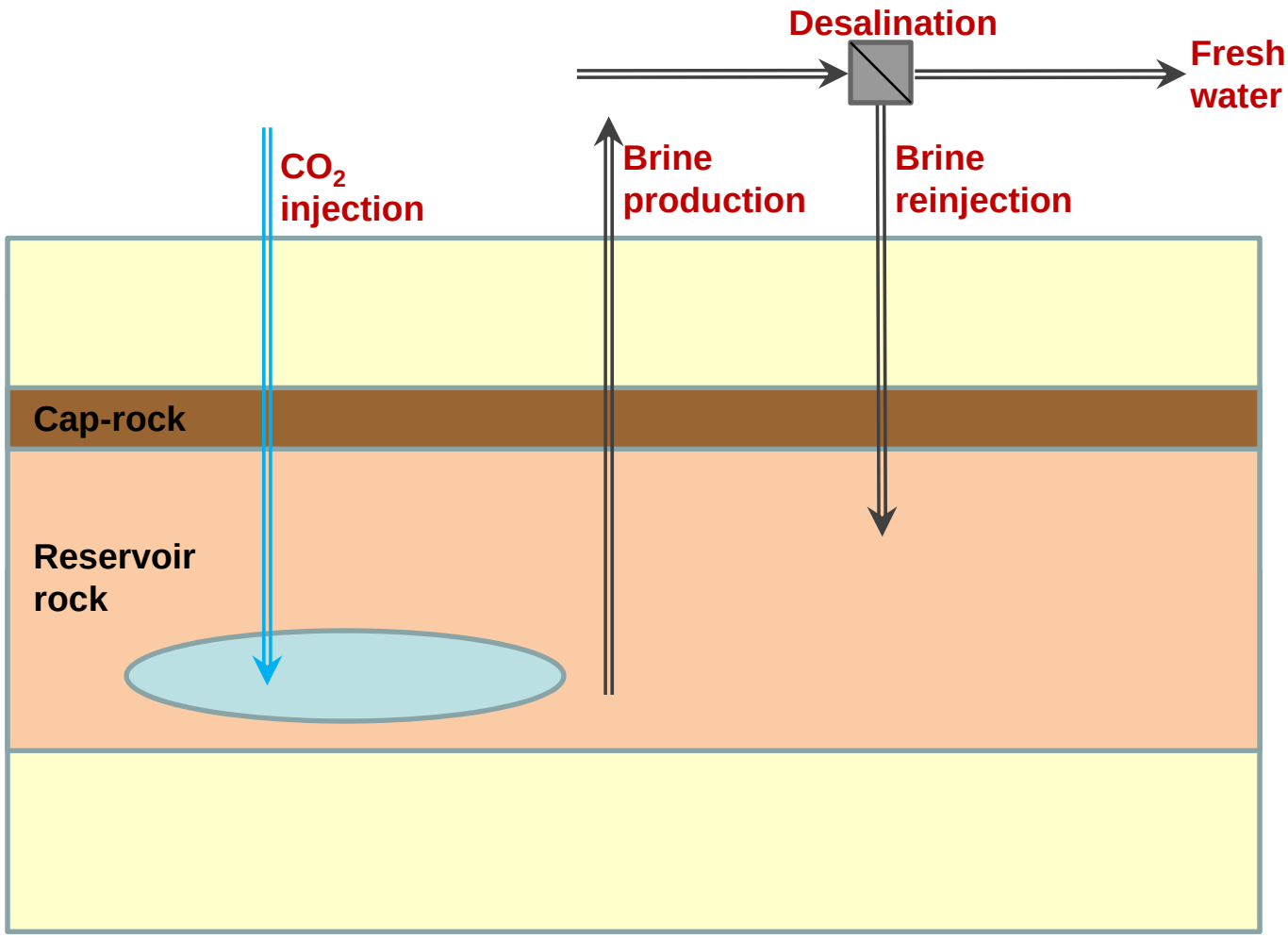
We believe production and treatment of saline aquifer waters can benefit CCS

- **Extraction of saline waters from carbon storage sites can:**
  - **Produce fresh water**
  - **Increase CO_2 storage volume and reduce footprint**
  - **Reduce CO_2 storage risk**
    - **Allow reservoir pressure management**
    - **Prevent induced seismicity**
- **Provided that:**
  - **The brines are treatable (chemistry)**
  - **The costs are favorable**



We will desalinate aquifer brines to create fresh water and space for additional CO_2 storage



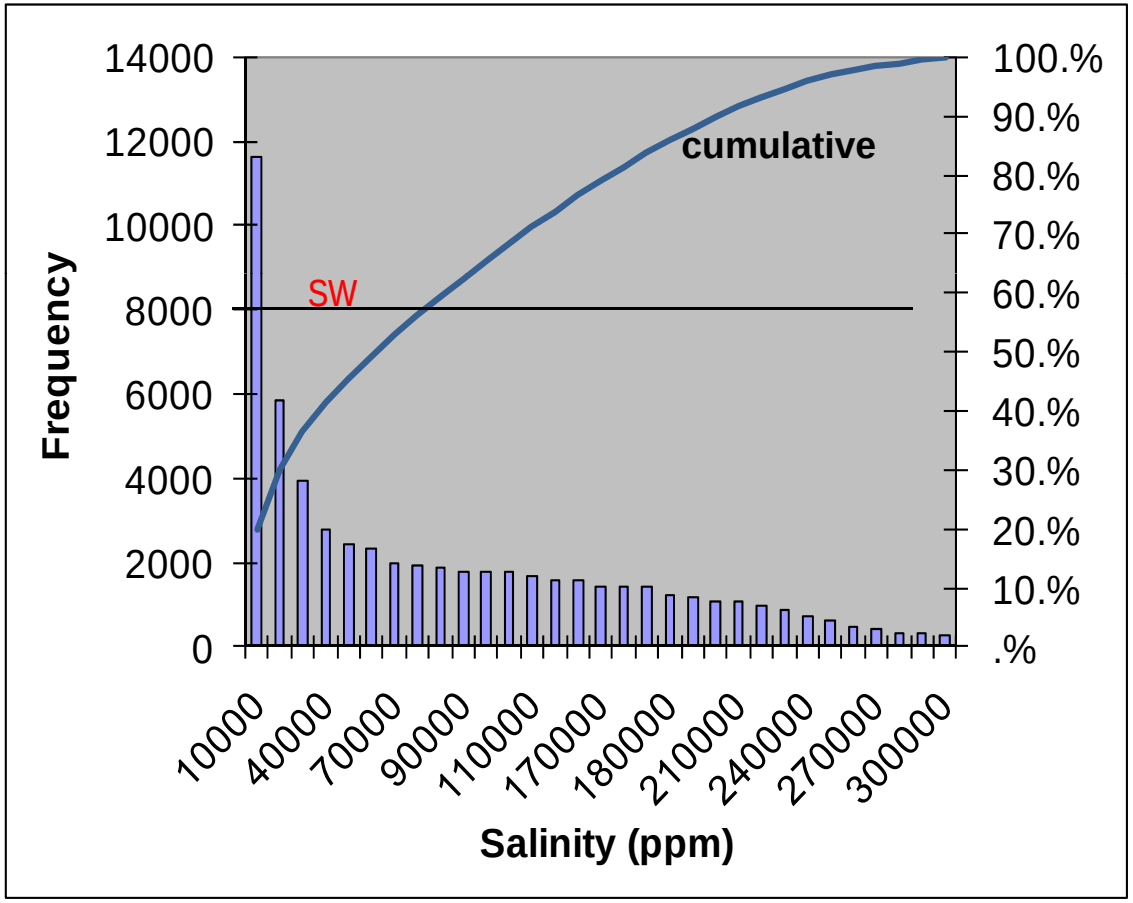
Process:

1. Produce water from neighboring well
2. Desalinate
3. Reinject the concentrate

Treating displaced brine to make fresh water could:

- Help manage pressure in the saline aquifer
- Provide half the energy plant's operating water

Roughly ½ of the world's saline aquifers are suitable for standard reverse osmosis treatment

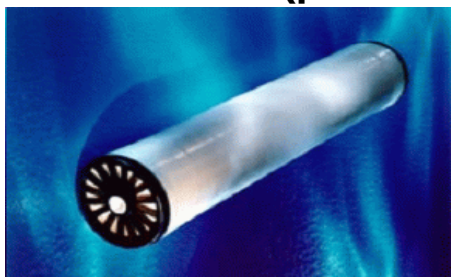


Treatment Feasibility

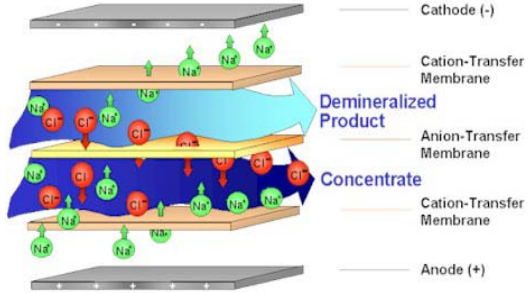
Salinity (ppm)	Method
10,000-40,000 mg/L:	Standard RO
40,000-85,000 mg/L:	Low-recovery RO
85,000-300,000 mg/L:	Multi-stage NF+RO
> 300,000 mg/L:	Not treatable

Several desalination technologies exist - none are energy efficient

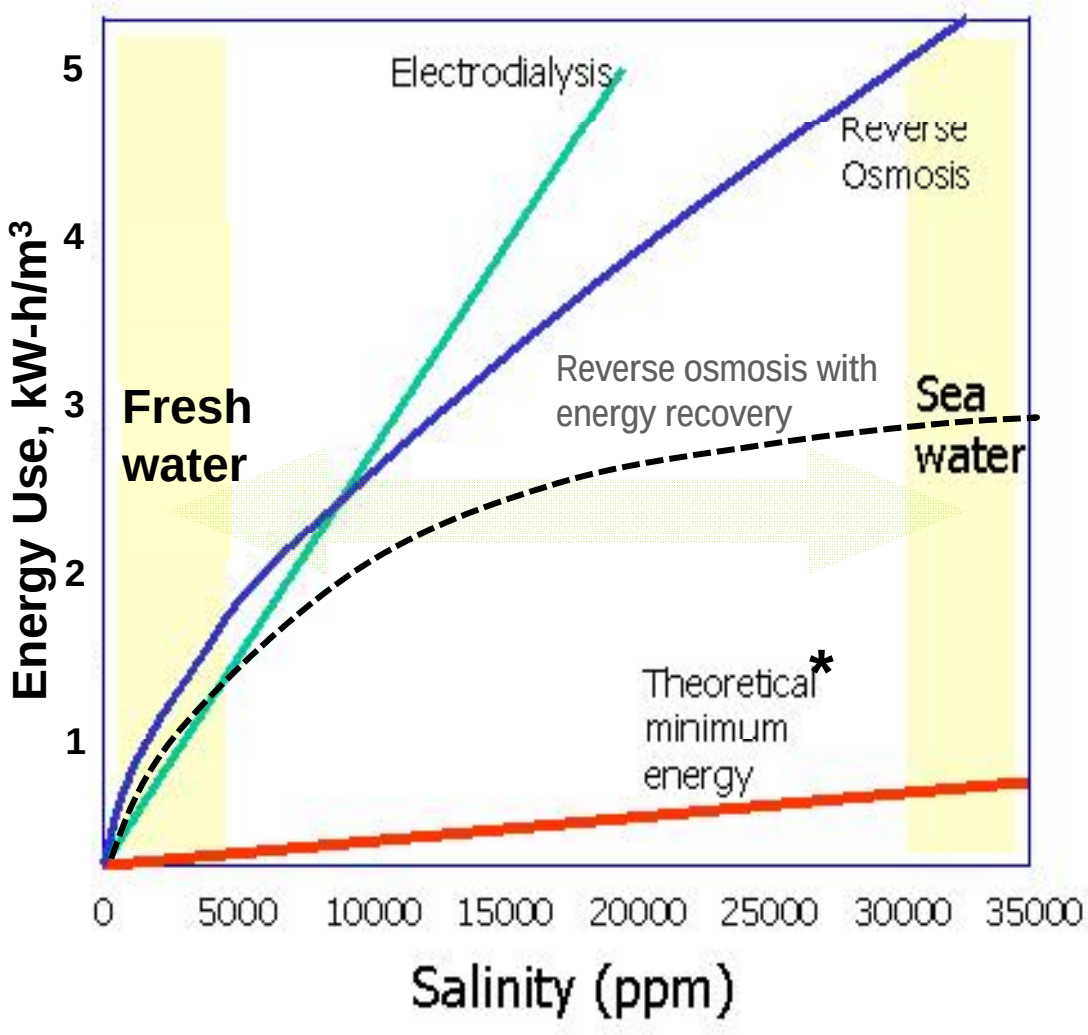
Reverse osmosis and Nanofiltration (pressure)



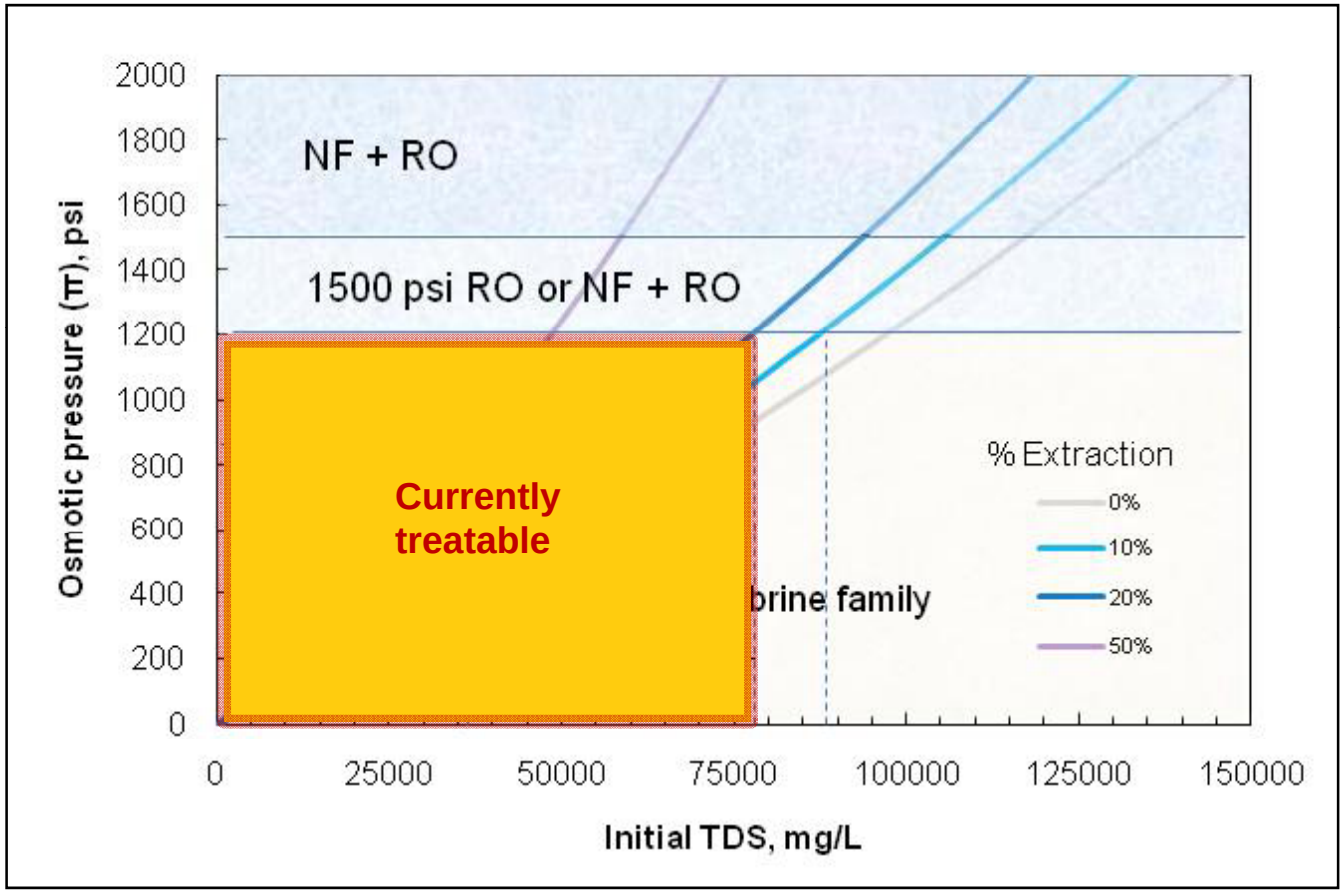
Electrodialysis and Capacitive Deionization (charge)



Distillation (heat)



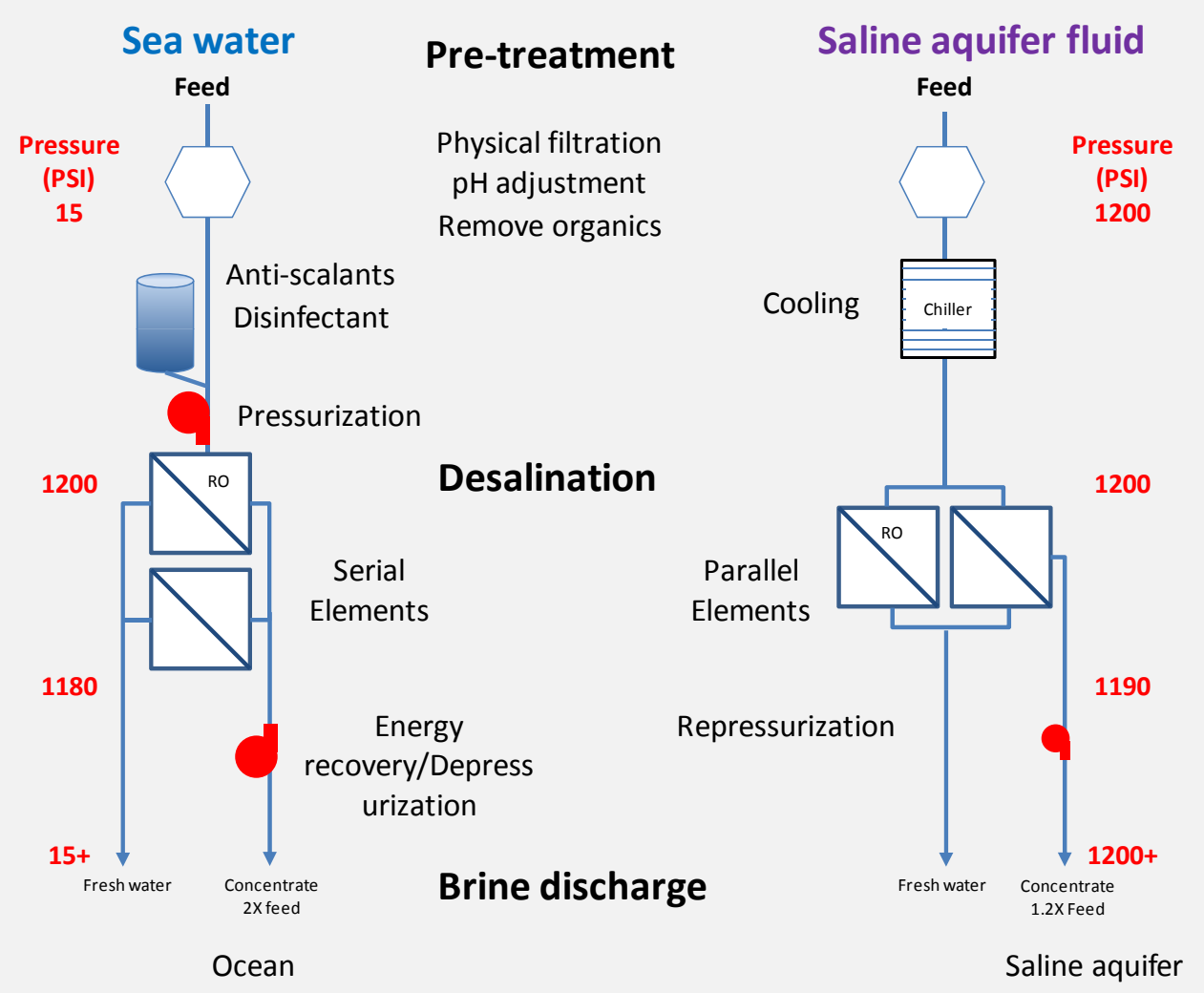
Osmotic pressure limits the salinity of brines that can be desalinated using reverse osmosis



RO = Reverse Osmosis
NF = Nanofiltration

%Extraction = amount of water separated from brine

A modified sea water RO system is recommended for desalination of saline aquifer fluids



Key differences:

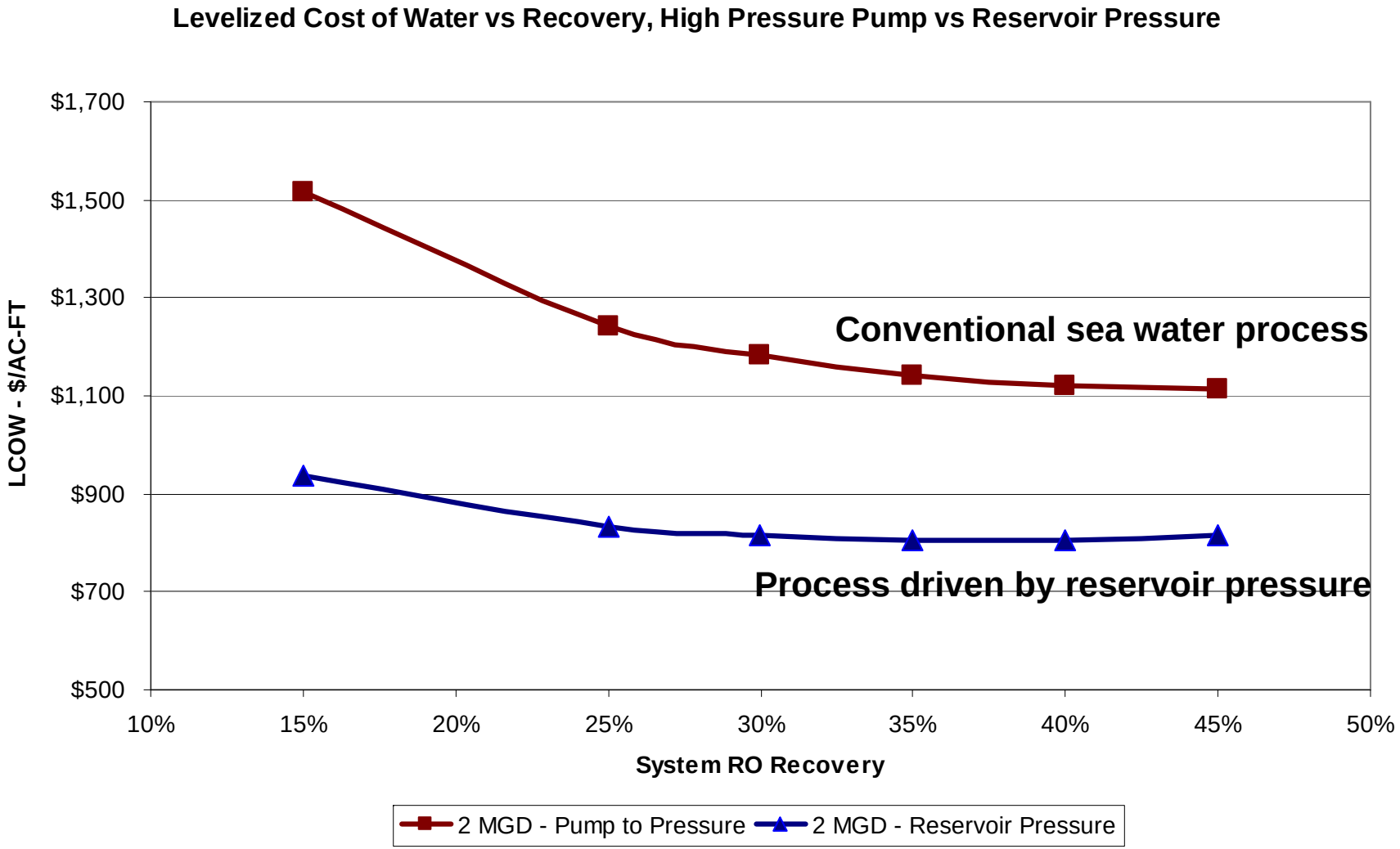
Pretreatment:
- **less bio control**
- **more scale control**
- **anoxic**

Chiller needed to cool fluid to working range for polymer membranes

Pressurized fluid allows low recovery:
- **no high P pump**
- **less scaling**
- **longer membrane lifetime**
- **lower pressure for given TDS**
- **Need high P for reinjection**

No energy recovery step

Water costs are relatively low if process energy is supplied by reservoir pressure

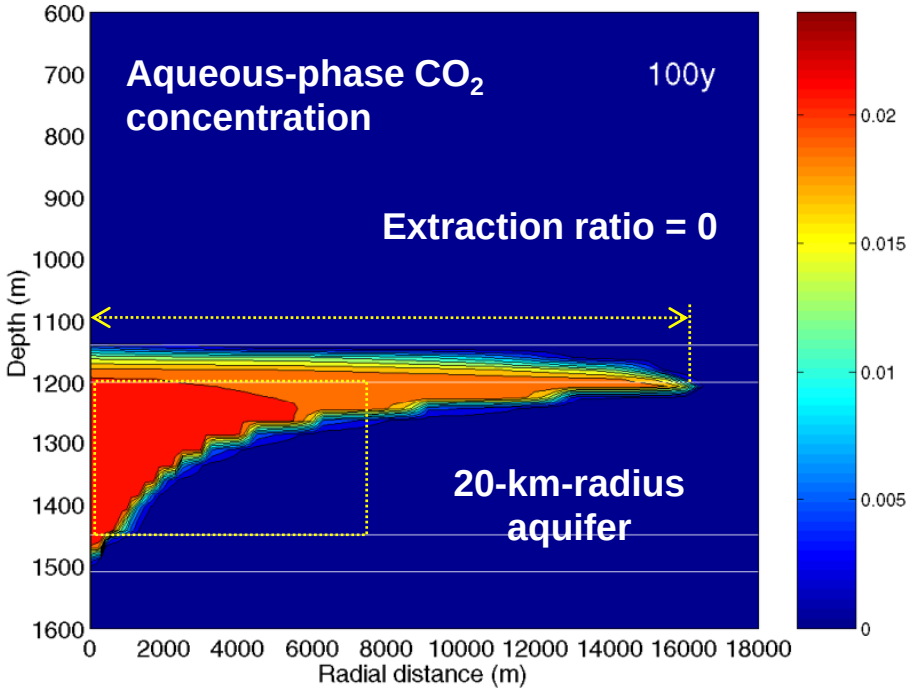


One can actively manage the reservoir through producing and treating water

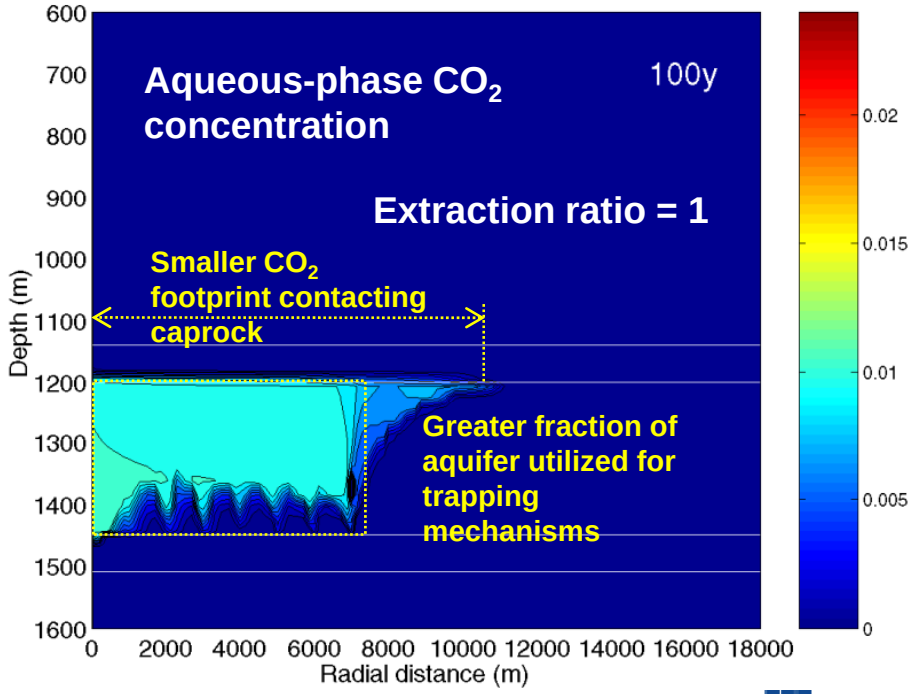
Active CO_2 Reservoir Management provides several benefits

- Reduces CO_2 plume footprint and increases resource use
- Greatly reduces pressure buildup and attendant risks (e.g., seismicity)
- Allows for Enhanced Water Recovery

Passive CO_2 Reservoir Management

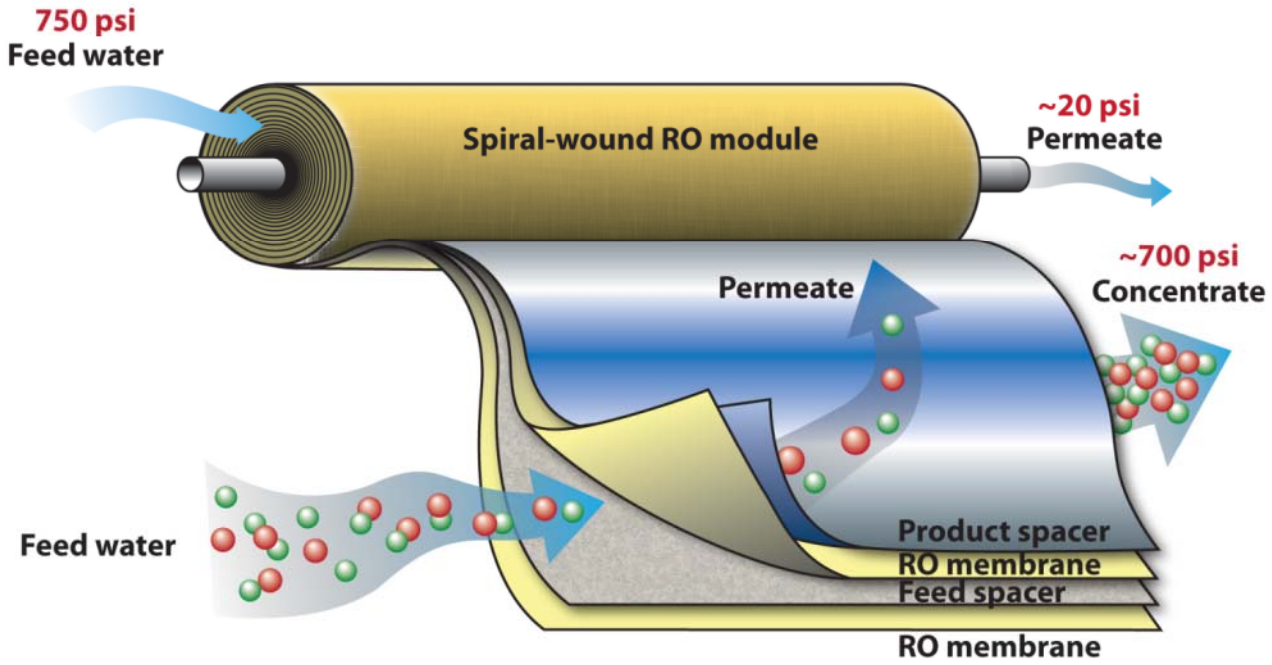


Active CO_2 Reservoir Management



The current P-T limits of reverse osmosis can be expanded by using stronger spacing materials

The polyamide membrane is <u>not</u> the limiting factor



With a relatively low-risk R&D effort we could build an RO element that functions up to 150°C and 100 bars, and desalinate brines with salinities of 15 wt %

We can produce water at sequestration sites for low cost, reducing environmental footprint and adding value

How much water are we talking about?

For 1000 MW coal plant:

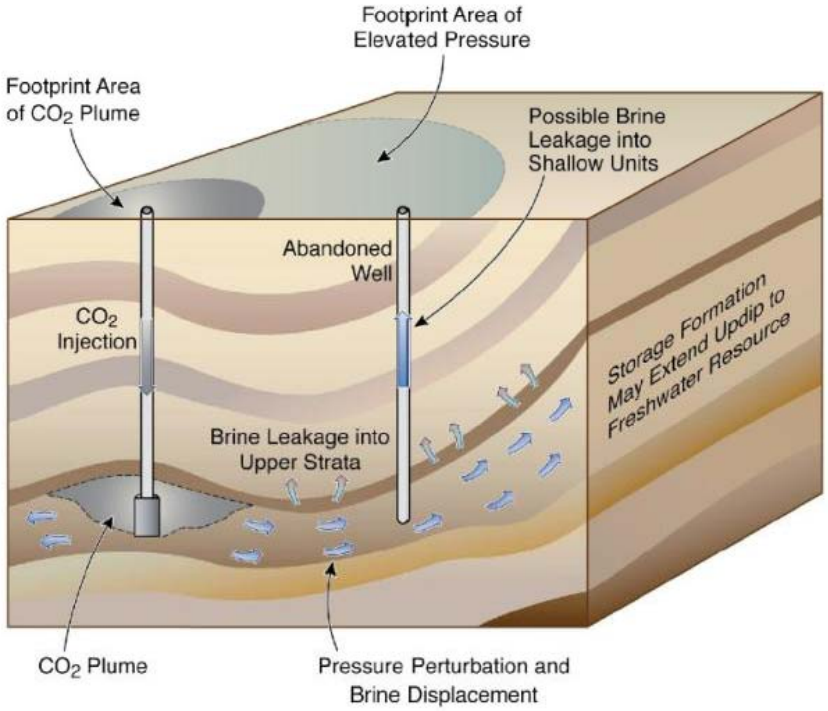
3 million tons CO_2 = 4 million m^3 water

- 3000 acre-feet
- Serve 5000 homes
- Irrigate 1000 acres of crops
- Provide half the cooling water needed for the plant

Rules of thumb for RO desalination costs:
Capital cost = 3.5-4.5 times gallons per day (GPD) product capacity
Total cost = $0.5-1 per m^3 product (2-4¢/gallon)

Summary

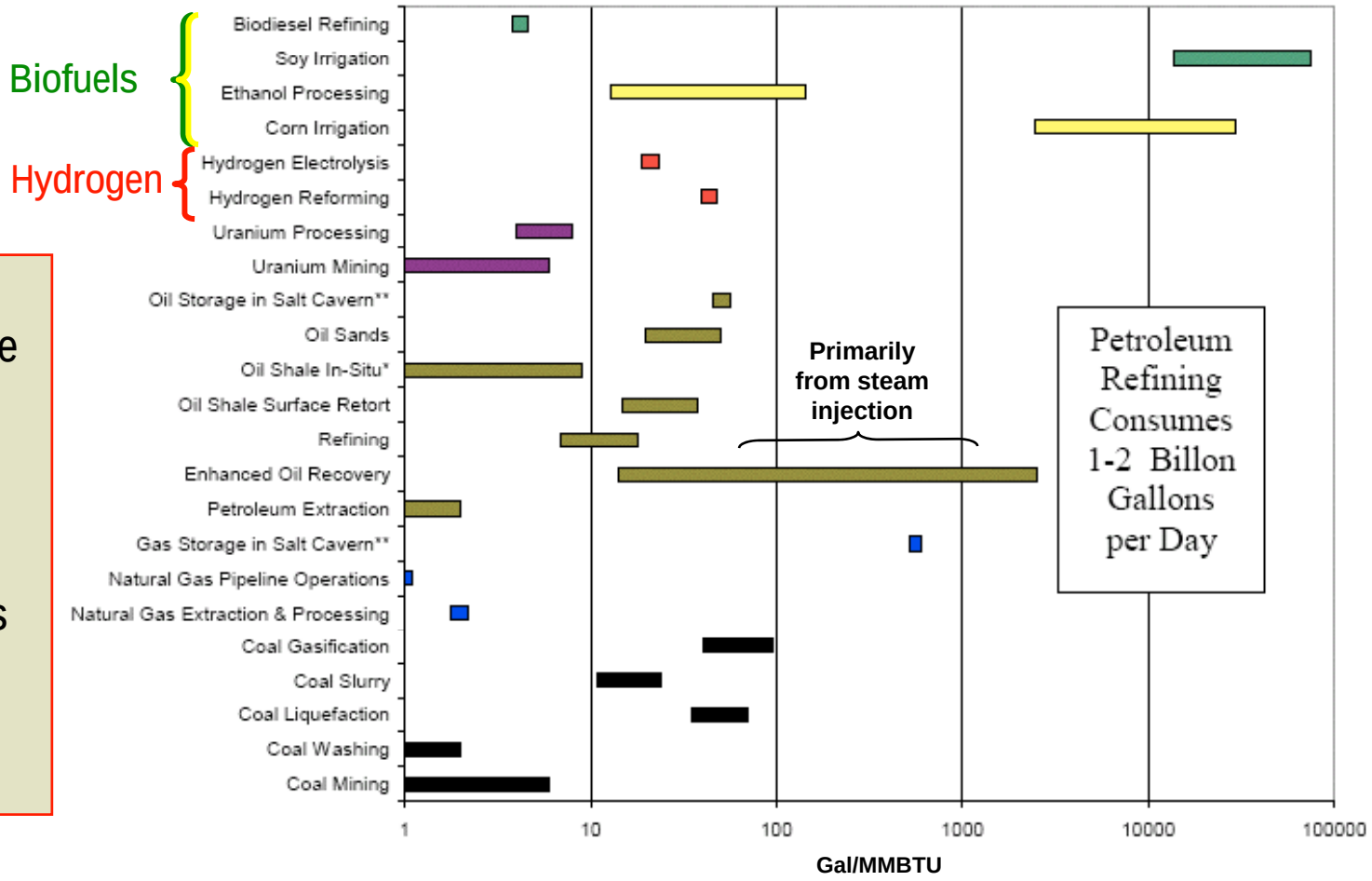
- **Extraction of saline waters from carbon storage sites can:**
  - **Produce potable water from about half of the available subsurface brines**
  - **Produce fresh water at about $800/AF**
  - **Reduce CO_2 storage risk**
    - **Substantially reduce the footprint of the CS site**
    - **Limit and reduce the maximum pressure of the reservoir**



BACKUP

Future energy development will put new demands on water resources

Water Used for Fuel Extraction and Processing

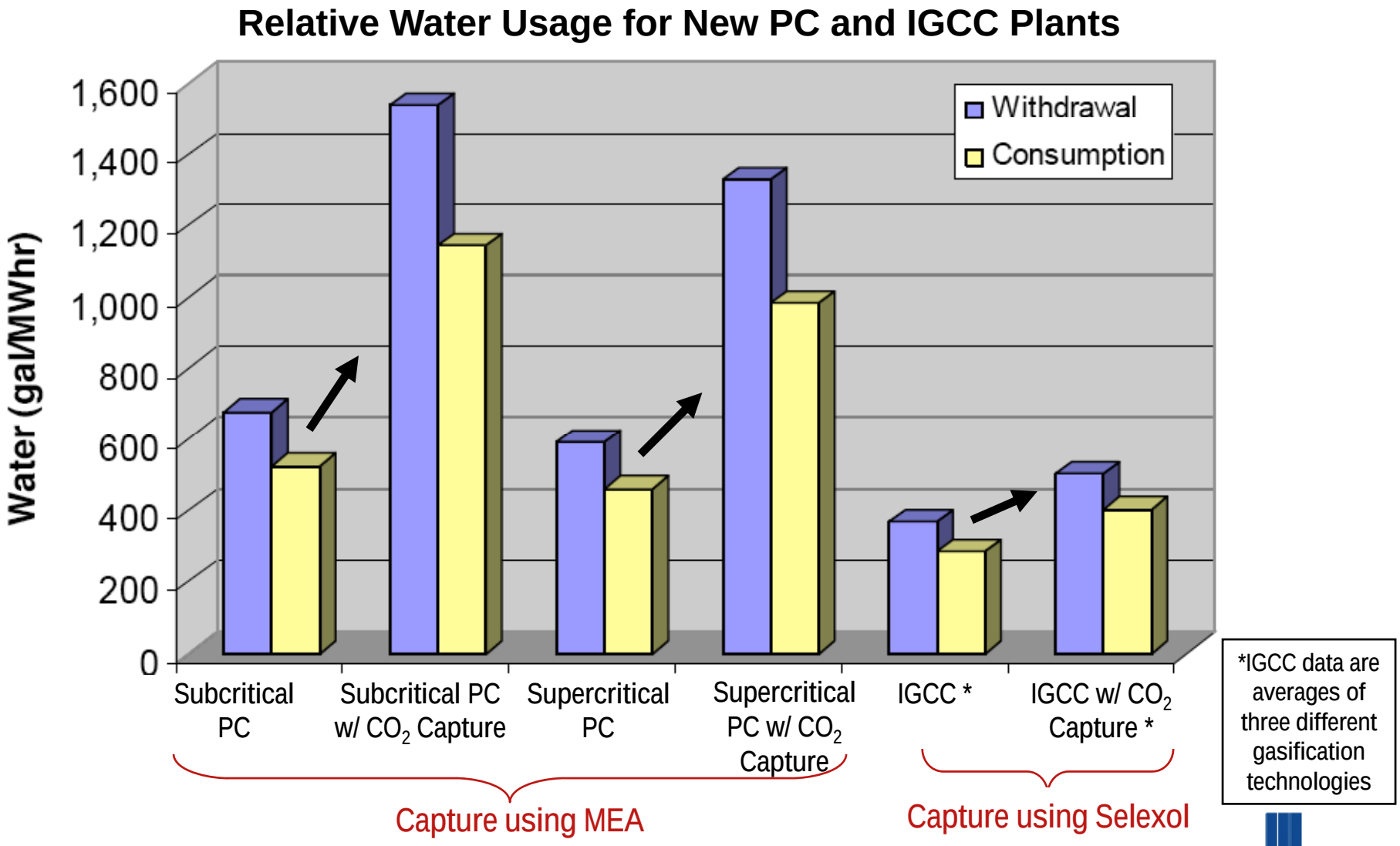


Many new technologies are more water intensive, increasing demands on water resources

- Biofuels
- Hydrogen

Constraints will grow for energy development and power plant siting

Conventional capture technologies increase overall water usage



Source: DOE-NETL *Estimating Freshwater Needs For Thermoelectric Generation*, 2007

Nanofiltration provides one path to treat high salinity brines

- Removal of divalent ions makes water directly usable as cooling water - even at high TDS
- Lowering of TDS may allow subsequent treatment using reverse osmosis